

BARRIER FILM DEPOSITION OVER METAL FOR REDUCTION IN METAL
DISHING AFTER CMP

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BARRIER FILM DEPOSITION OVER METAL FOR REDUCTION IN METAL
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TECHNICAL FIELD OF THE INVENTION

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The present invention is directed, in general, to chemical mechanical polishing during formation of integrated circuits and, more specifically, to chemical mechanical polishing of a primarily chemical nature of conformal layers within integrated circuits.

BACKGROUND OF THE INVENTION

A key process for forming metal regions within integrated circuits is chemical mechanical polishing (CMP), which involves mechanical polishing of a substrate's active layer surface utilizing an abrasive slurry containing chemicals which react with--and aid in the removal of--the target material on the substrate surface. For tungsten (W) metal layers, for instance, the abrasive slurry employed in chemical mechanical polishing will typically include one or more chemical substances which oxidize the tungsten metal and remove the oxidized tungsten.

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A primary benefit of chemical mechanical polishing, in general, is planarization of the upper surface of the integrated circuit structures on the substrate. For conformal layers, in particular, chemical mechanical polishing is useful in producing planar upper surfaces since higher regions of the layer (e.g., those overlying the interlevel dielectric) are removed before lower regions (e.g., those within contact or via openings and the like), and since other materials such as the interlevel dielectric are also removed. Planar upper surfaces facilitate photolithography and other processes required for formation of additional layers and/or structures over the polished layer.

Chemical mechanical polishing of tungsten, however, is highly chemical in nature. Tungsten removal by known chemical mechanical polishing processes is quite uniform across the surface of the layer, and is nearly independent of topography. This results in excessive removal of tungsten and "dishing" of the remaining tungsten regions. For example, FIGURE 3A illustrates a tungsten metal layer 300 formed conformally over an interlevel dielectric 301, where the dielectric layer 301 is patterned to produce three different types of conductive structures after chemical mechanical polishing: tungsten contacts or vias

within openings 302; tungsten interconnects formed by the damascene method within grooves 303 (shown in cross-section and having an extended length not visible in the view illustrated); and tungsten capacitive electrodes for metal oxide semiconductor (MOS) capacitors within trough 304 (also shown in cross-section and having an extended length, which is not visible, for a total area proportional to the desired capacitance).

FIGURE 3B illustrates the integrated circuit structure of FIGURE 3A at an intermediate point during a chemical mechanical polishing process employed to pattern the tungsten metal layer by removal of the portions overlying interlevel dielectric 301. After partial removal of the tungsten layer by chemical mechanical polishing, tungsten layer 305 remains but, because removal of the tungsten layer by chemical mechanical polishing is largely uniform, is already beginning to dish in lower regions 306 and 307 and is not planarized. Dishing may be particularly pronounced in lower regions 307 having a large area, such as the region 304 for forming MOS capacitor electrode, and less extreme in lower regions having a smaller area (e.g., regions 302 for contacts or vias).

FIGURE 3C illustrates the integrated circuit structure of FIGURE 3A after completion of a chemical mechanical

polishing process employed to pattern the tungsten metal layer, after complete removal of the portions overlying interlevel dielectric 301. The remaining tungsten regions 308 exhibit substantial dishing, and the tungsten layer may be completely removed in some regions 309.

Dishing of tungsten metal layers patterned by chemical mechanical polishing may cause several problems. Dishing of tungsten plugs within contact or via openings exposes the tungsten plug to slurry contamination, which leads to severe interconnect failures. Dishing of interconnects may causes shorts or thin, high resistance points within the conductive path. Dishing of capacitor electrodes, particularly if the tungsten is completely removed at points, may result in a different capacitance than intended.

There is, therefore, a need in the art for a process of mitigating dishing during chemical mechanical polishing of conformal tungsten layers.

SUMMARY OF THE INVENTION

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To address the above-discussed deficiencies of the prior art, it is a primary object of the present invention to provide, for use in forming conductive structures within an integrated circuit, a protective barrier layer, formed of a material such as titanium or titanium nitride for which removal by chemical mechanical polishing (CMP) is primarily mechanical rather than primarily chemical, on a conformal tungsten layer. During subsequent CMP to pattern the tungsten layer, upper topological regions of the protective barrier layer (such as those overlying interlevel dielectric regions) are removed first, exposing the tungsten under those regions to removal, while protective barrier layer regions over lower topological regions (such as openings within the interlevel dielectric) remain to prevent chemical attack of underlying tungsten. CMP patterned tungsten is thus substantially planar with the interlevel dielectric without dishing, even in large area tungsten structures such as MOS capacitor structures.

The foregoing has outlined rather broadly the features and technical advantages of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional

features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art will appreciate that they may readily use the conception and the specific embodiment disclosed as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. Those skilled in the art will also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

Before undertaking the DETAILED DESCRIPTION OF THE INVENTION below, it may be advantageous to set forth definitions of certain words or phrases used throughout this patent document: the terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation; the term "or" is inclusive, meaning and/or; and the phrases "associated with" and "associated therewith," as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, or the like. Definitions for certain words and phrases are provided throughout this patent document, and those of

ordinary skill in the art will understand that such definitions apply in many, if not most, instances to prior as well as future uses of such defined words and phrases.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, wherein like numbers designate like objects, and in which:

FIGURES 1A-1C depict cross-sections of an integrated circuit structure during various stages of a process for selectively forming tungsten metal regions by chemical mechanical polishing according to one embodiment of the present invention;

FIGURES 2A-2B depict cross-sections of an integrated circuit structure during various stages of a process for selectively forming tungsten metal regions by chemical mechanical polishing according to another embodiment of the present invention; and

FIGURES 3A-3C depict cross-sections of an integrated circuit structure during various stages of a known process for selectively forming tungsten metal regions by chemical mechanical polishing.

DETAILED DESCRIPTION OF THE INVENTION

Only those portions of the structures and/or processes employed to fabricate a complete integrated circuit which are unique to the present invention, or which are required for an understanding of the present invention, are described below and/or depicted in the referenced figures. Nonetheless, the present invention may be practiced in conjunction with such other structures and processes to form a completed integrated circuit.

FIGURES 1A through 2B, discussed below, and the various embodiments used to describe the principles of the present invention in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the invention. Those skilled in the art will understand that the principles of the present invention may be implemented in any suitably arranged device.

FIGURES 1A-1C depict cross-sections of an integrated circuit structure during various stages of a process for selectively forming tungsten metal regions by chemical mechanical polishing according to one embodiment of the present invention. Interlevel dielectric layer 100 is formed over a substrate 101, and over any layers formed on

the substrate such as lower metallization levels, and selectively patterned to include openings therethrough for formation of various conductive structures.

By way of example, contact or via openings 102 are formed through the dielectric layer 100 over underlying conductive regions (not shown) such as a source/drain region within the substrate, a gate electrode, or an interconnect, contact or landing pad within a lower metallization level. Grooves 103 are formed for lateral interconnects (signal lines) extending over an insulating region for a length (not shown) within the dielectric layer 100. Trough 104 is formed over an insulating layer and a conductive region within the substrate (not shown) to define a region for a capacitive electrode within an MOS capacitor. Openings for formation of other conductive structures may also be formed within dielectric layer 100.

In the exemplary embodiment, a multilayer conformal barrier and/or adhesion layer including a titanium (Ti) layer 105 and a titanium nitride (TiN) layer 106 is formed over the dielectric layer 100 and within the openings 102-104. Other barrier/adhesion structures such as a TiN-Ti-TiN layer may alternatively be employed. A conformal tungsten bulk metal layer 107 is formed on the barrier layers 105 and 106 to a thickness of 4500-8000 angstroms.

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5 In the present invention, a protective or barrier layer 108 is formed on the tungsten layer 107. Protective barrier layer 108 is formed of a material for which chemical mechanical polishing is primarily mechanical rather than primarily chemical, as is the case with tungsten. Instead of being uniformly removed by chemical mechanical polishing, higher topological portions (thus furthest from the substrate body 101) of the layer 108 are removed before lower topological regions, and layer 108 thus exhibits a planarization efficiency which is much larger than that of tungsten. Suitable materials for protective barrier layer 108 include titanium and titanium nitride, for which removal by chemical mechanical polishing depends largely on mechanical energy.

20 Protective barrier layer 108 may be formed to a thickness of between about 100 and 800 angstroms, depending upon the chemical mechanical polishing process employed and the size of the conductive structures being patterned. Dishing becomes more prevalent as the dimensions of the tungsten structure increase, and certain large area conductive structures (such as capacitor electrodes) are therefore most susceptible.

FIGURE 1B illustrates the integrated circuit structure of FIGURE 1A at an intermediate point during a chemical

mechanical polishing process employed to pattern the tungsten metal layer by removal of the portions overlying interlevel dielectric 100. As noted above, higher topological portions of the protective barrier layer 108 are removed first by chemical mechanical polishing, leaving the protective barrier layer regions 109 over the lower topological regions (i.e., those corresponding to openings 102-104 within dielectric layer 100) to protect the underlying tungsten in those regions from chemical attack. Exposed portions 110 of the tungsten layer 107 where the protective barrier layer 108 is removed are oxidized and abraded for removal. However, the remaining portions 109 of the protective barrier layer do not allow oxidation of the tungsten covered by those regions 109.

FIGURE 1C illustrates the integrated circuit structure of FIGURE 1A after completion of a chemical mechanical polishing process employed to pattern the tungsten metal layer 107, after complete removal of the portions of tungsten layer 107 overlying interlevel dielectric 100. In this embodiment, the protective barrier layer is completely removed by chemical mechanical polishing, together with portions of the tungsten and barrier layers overlying the dielectric layer 100. The remaining portions of the tungsten layer 111 within openings 102-104, not removed by

the chemical mechanical polishing, are substantially planar with the dielectric layer 102.

FIGURES 2A-2B depict cross-sections of an integrated circuit structure during various stages of a process for selectively forming tungsten metal regions by chemical mechanical polishing according to another embodiment of the present invention. The basic structure and process is identical to that depicted in FIGURES 1A through 1C and described above. In this embodiment, however, the tungsten layer 200 is formed with a thickness which is insufficient to fill the openings 102-104 (i.e., less than the thickness of dielectric layer 100), although the overlying protective barrier layer 108 fills any remainder of openings 102-104 not filled by tungsten layer 200.

FIGURE 2B illustrates the integrated circuit structure of FIGURE 2A after completion of a chemical mechanical polishing process employed to pattern the tungsten metal layer 200, after complete removal of the portions of tungsten layer 200 overlying interlevel dielectric 100. At a result of the reduced thickness of the tungsten layer 200, after completion of the chemical mechanical polishing process and removal of the portions of the protective barrier layer 108, tungsten layer 200, and barriers layer 105 and 106 which overlying the dielectric layer 100,

portions 202 of the protective barrier layer remain, together with portions 201 of the tungsten layer, within the openings 102-104. If titanium or titanium nitride is employed as the protective barrier layer, however, these remaining portions 202 may simply contribute to the barrier layer for the next metallization level.

The present invention allows tungsten to be reliably patterned by chemical mechanical polishing by reducing dishing, particularly for tungsten regions having a large area. Improved process margins and yield are thereby provided by the present invention.

Although the present invention has been described in detail, those skilled in the art will understand that various changes, substitutions and alterations herein may be made without departing from the spirit and scope of the invention in its broadest form.